Claims

1. Method for providing a substrate structure for oriented neurite outgrowth, wherein a basic substrate (1) is provided,
characterized in that
at least one alignment layer (2) is deposited on said substrate (1) and
a mono- or multi-layer of a liquid crystal material (3) is deposited on said at least one alignment layer (2); or
a combined alignment layer is deposited on said basic substrate (1), thereby providing a structured surface.

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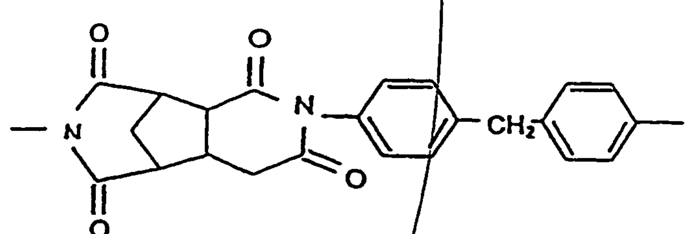
2. Method according to claim 1, characterized in that at least one neuron or cell (10) is put on top of said substrate structure (1, 2, 3) within a culture medium.

3. Method according to claim 1 ~~or 2,~~ characterized in that said structured surface (3) has areas of different surface free energies.

4. Method according to ~~one of the preceding~~ claim~~s~~, characterized in that said at least one alignment layer (2) is a polymeric alignment layer.

5. Method according to ~~one~~ of ~~the preceding~~ claim~~s~~, characterized in that said alignment layer (2) material is a polyimide.

6. Method according to claim 5, characterized in that said polyimide is represented by the following structure:



7. Method according to ~~one of the preceding~~ claim~~s~~ 1, characterized in that said liquid crystal layer (3) material is 4-Octyl-4-biphenyl carbonitrile (8CB) and/or 4-Pentyl-4-biphenyl carbonitrile (5CB).

8. Method according to ~~one of the preceding~~ claim~~s~~ 1, characterized in that said alignment layer (2) material is dissolved and the solution is applied to the substrate (1).

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9. Method according to claim 8, characterized in that said solution of the alignment layer (2) material is spin coated on the substrate (1).

10. Method according to claim 8 ~~or 9~~, characterized in that an annealing process is conducted after applying the alignment layer solution to the substrate (1).

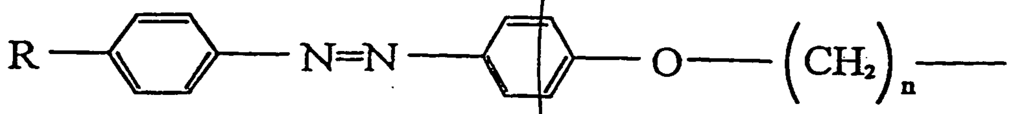
11. Method according to ~~one of the preceding~~ claim~~s~~ 1, characterized in that said liquid crystal layer (3) material is solved, preferably in chloroform, and the solution is applied onto said alignment layer (2).

12. Method according to claim 11, characterized in that said solution of liquid crystal material is evaporated onto said alignment layer (2).

13. Method according to one of the claim~~s~~ 1 ~~to 3~~, characterized in that said combined alignment layer comprises polymeric material selected from the group comprising polyester, polypeptide, polyacrylamide, polyvinyl alcohol, polyacrylate, polymethacrylate, polyurea and polyamide.

14. Method according to claim 13, characterized in that said polymeric material has at least one azobenzene chromophore covalently attached.

15. Method according to claim 14, characterized in that said azobenzene chromophore is represented by the formula:



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where R is selected from the group comprising CN, NO_2, OCH_3, H, CH_3, $(CH_2)_3CH_3$, F, Cl, Br, CF_3, C_6H_5, $O(CH_2)_2OCH_3$ and $(CH_2)_5CH_3$,
and where n is selected from the range: $0 \leq n \leq 12$.

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16. Method according to ~~one of the~~ claims 13-15, characterized in that said polyester is a sidechain liquid-crystalline polyester.

17. Method according to claim 16, characterized in that said side chain liquid-crystalline polyester is an azobenzene sidechain liquid-crystalline polyester.

18. Method according to claim 17, characterized in that said azobenzene sidechain liquid-crystalline polyester is selected from the group comprising P6a12, P6a10, P8a10, P10a10, P8a12 and P10a12.

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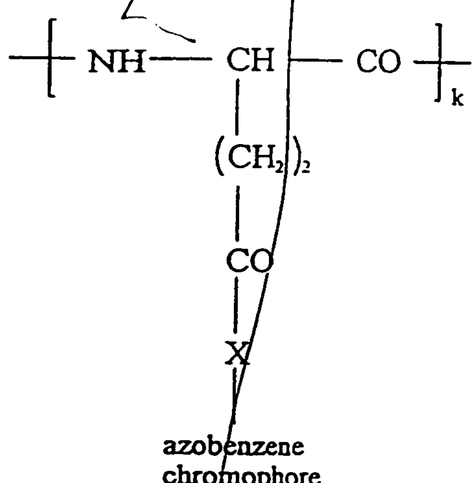
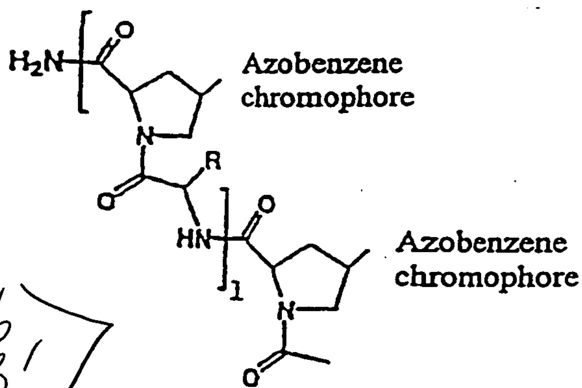
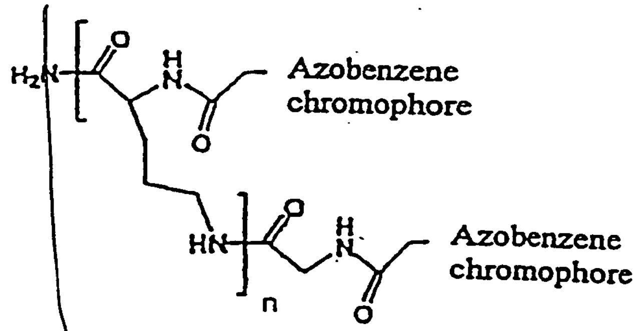
19. Method according to ~~one of the~~ claims 13-15, characterized in that said polypeptide is selected from the group comprising polyglutamate, polyproline and polyornithine.

20. Method according to claim 19, characterized in that said polypeptide is selected from the group comprising







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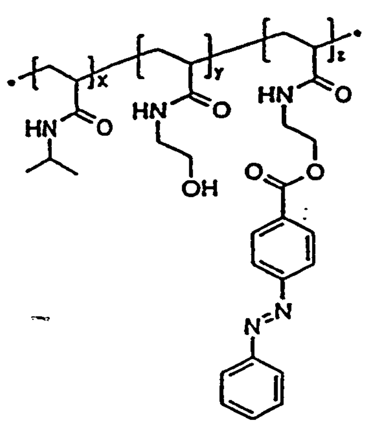
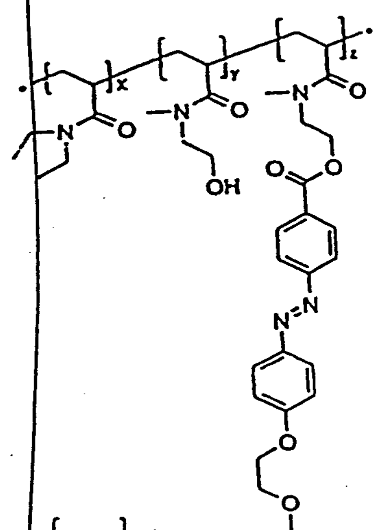
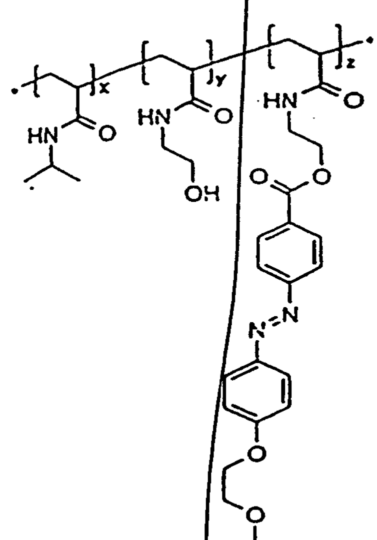
where X is selected from the group comprising NH and O,
where the azobenzene chromophore is defined as in claim 15, and
where k, n and l are selected from the range: $1 \leq (k \text{ or } l \text{ or } n) \leq 500$.

21. Method according to ~~one of the~~ claims 13 – 15, characterized in that said polyacrylamide is selected from the group comprising







where x is selected from the range: $0.2 \leq x \leq 1$,
y is selected from the range: $0.1 \leq y \leq 1$,
z is selected from the range: $0.005 \leq z \leq 0.025$, and
$x + y + z = 1$ for all combinations of x, y and z.

22. Method according to ~~one of~~ the claim~~s~~ 13 ~~- 15~~, characterized in that said polyvinyl alcohol is selected from the group comprising

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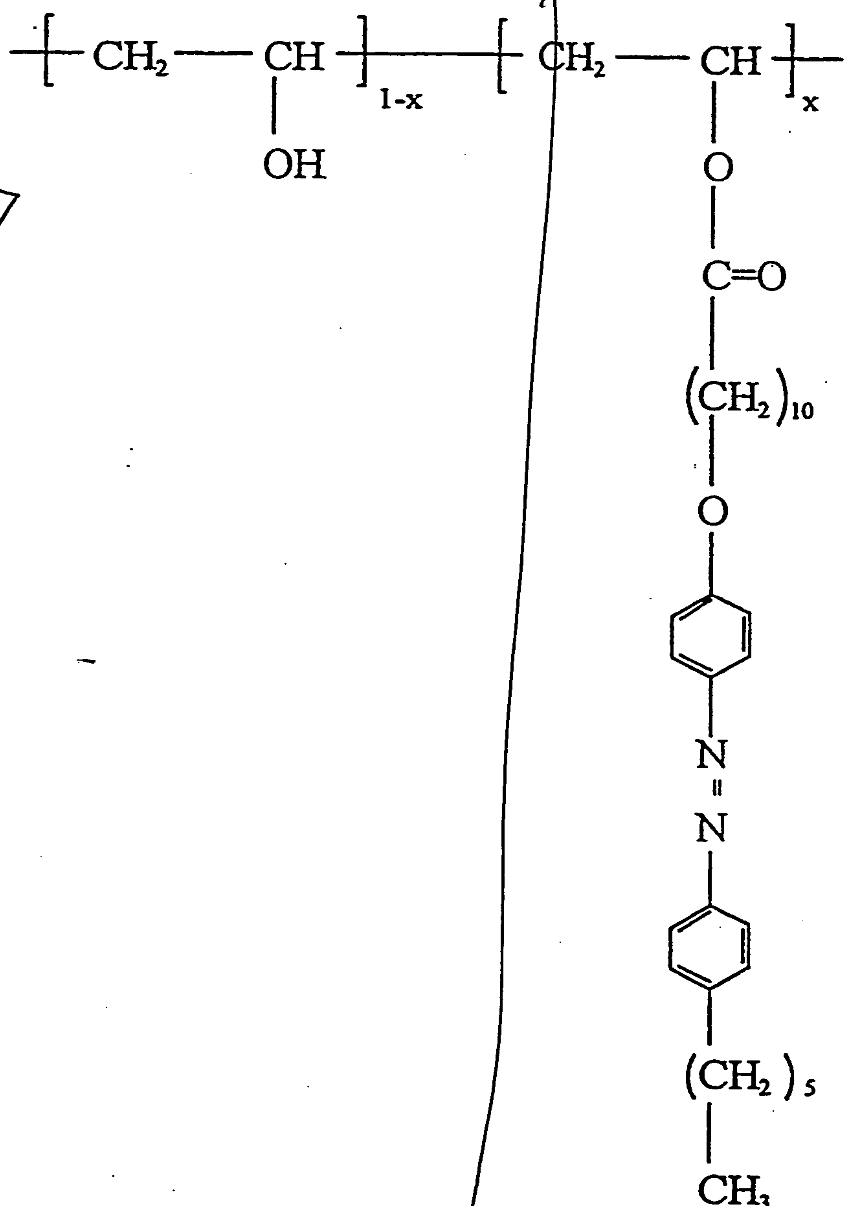

where x is selected from the range: $0.2 \leq x \leq 0.6$.

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23. Method according to ~~one of~~ the claim~~s~~ 1 ~~to 3~~, characterized in that said combined alignment layer comprises at least one type of azosilane.

24. Method according to claim 23, characterized in that said azosilane is selected from the group comprising

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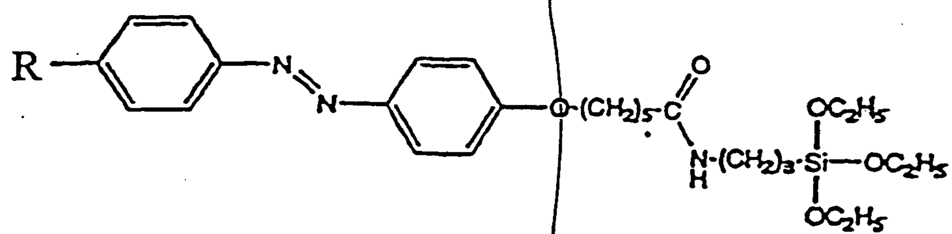

where R is selected from the group comprising CN, NO_2, OCH_3, H, CH_3, $(CH_2)_3CH_3$, F, Cl, Br, CF_3, C_6H_5, $O(CH_2)_2OCH_3$ and $(CH_2)_5CH_3$.

25. Method according to ~~one of~~ the ~~preceding~~ claim~~s~~, characterized in that the orientation of the structured surface is directed by external means for controlling oriented neurite outgrowth.

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26. Method according to claim 25, characterized in that said structured surface is oriented by an electric field.

27. Method according to claim 25, characterized in that said structured surface is oriented by electromagnetic irradiation.

28. Method according to claim 27, characterized in that said electromagnetic irradiation is applied by laser means.

29. Method according to ~~one of the~~ claim~~s~~ 25 ~~to 28~~, characterized in that said directing or switching of said structured surface is conducted at a temperature, at which the liquid crystal material is in its nematic or in its smectic phase.

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30. Substrate structure for neurite outgrowth, comprising a basic substrate (1) ~~characterized in that~~

~~it further comprises~~

- an alignment layer (2) on said substrate (1), and
- a mono- or multi-layer of liquid crystal material (3) on said alignment layer; or comprises
- a combined alignment layer.

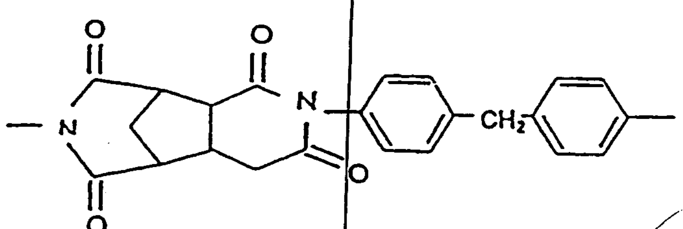
31. Substrate structure according to claim 30, characterized in that it further comprises at least one neuron or cell (10) on top of said substrate structure.

32. Substrate structure according to claim 30 ~~or 31~~, characterized in that said basic substrate (1) is a glass substrate, preferably covered with a conductive layer or an electrode arrangement.

33. Substrate structure according to ~~one of the~~ claim~~s~~ 30 ~~to 32~~, characterized in that said at least one alignment layer (2) is a polymeric alignment layer.

34. Substrate structure according to ~~one of~~ the claim~~s~~ 30 ~~to 33~~, characterized in that said alignment layer (2) is a polyimide.

35. Substrate structure according to claim 34, characterized in that said polyimide is represented by the following structure:



36. Substrate structure according to ~~one of the~~ claim~~s~~ 30 ~~to 35~~, characterized in that said liquid crystal material (3) is 4-Octyl-4-biphenyl carbonitrile (8CB) and/or 4-Pentyl-4-biphenyl carbonitrile (5CB).

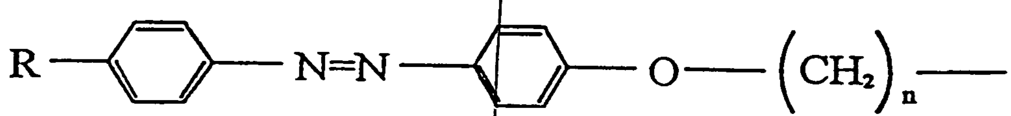
37. Substrate structure according to ~~one of~~ the claim~~s~~ 30 ~~to 36~~, characterized in that the alignment layer (2) has a thickness from 10 to 200 nm, preferably about 100 nm.

38. Substrate structure according to ~~one of the~~ claims 30 ~~to 37~~, characterized in that the liquid crystal layer (3) has a thickness from 10 to 150 nm, preferably about 100 nm.

39. Substrate structure according to ~~one of the~~ claims 30 ~~to 32~~, characterized in that said combined alignment layer comprises polymeric material selected from the group comprising polyester, polypeptide, polyacrylamide, polyvinyl alcohol, polyacrylate, polymethacrylate, polyurea and polyamide.

40. Substrate structure according to claim 39, characterized in that said polymeric material has at least one azobenzene chromophore covalently attached.

41. Substrate structure according to claim 40, characterized in that said azobenzene chromophore is represented by the formula:



where R is selected from the group ~~comprising~~ CN, NO_2, OCH_3, H, CH_3, $(CH_2)_3CH_3$, F, Cl, Br, CF_3, C_6H_5, $O(CH_2)_2OCH_3$ and $(CH_2)_5CH_3$,
and where n is selected from the range: $0 \leq n \leq 12$.

42. Substrate structure according to ~~one of the~~ claims 39 ~~- 41~~, characterized in that said polyester is a sidechain liquid-crystalline polyester.

43. Substrate structure according to claim 42, characterized in that said sidechain liquid-crystalline polyester is an azobenzene sidechain liquid-crystalline polyester.

44. Substrate structure according to claim 43, characterized in that said azobenzene sidechain liquid-crystalline polyester is selected from the group comprising P6a12, P6a10, P8a10, P10a10, P8a12 and P10a12. a1

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45. Substrate structure according to ~~one of the~~ claims 39~~-41~~, characterized in that said polypeptide is selected from the group comprising polyglutamate, polyproline and polyornithine.

46. Substrate structure according to claim 45, characterized in that said polypeptide is selected from the group comprising

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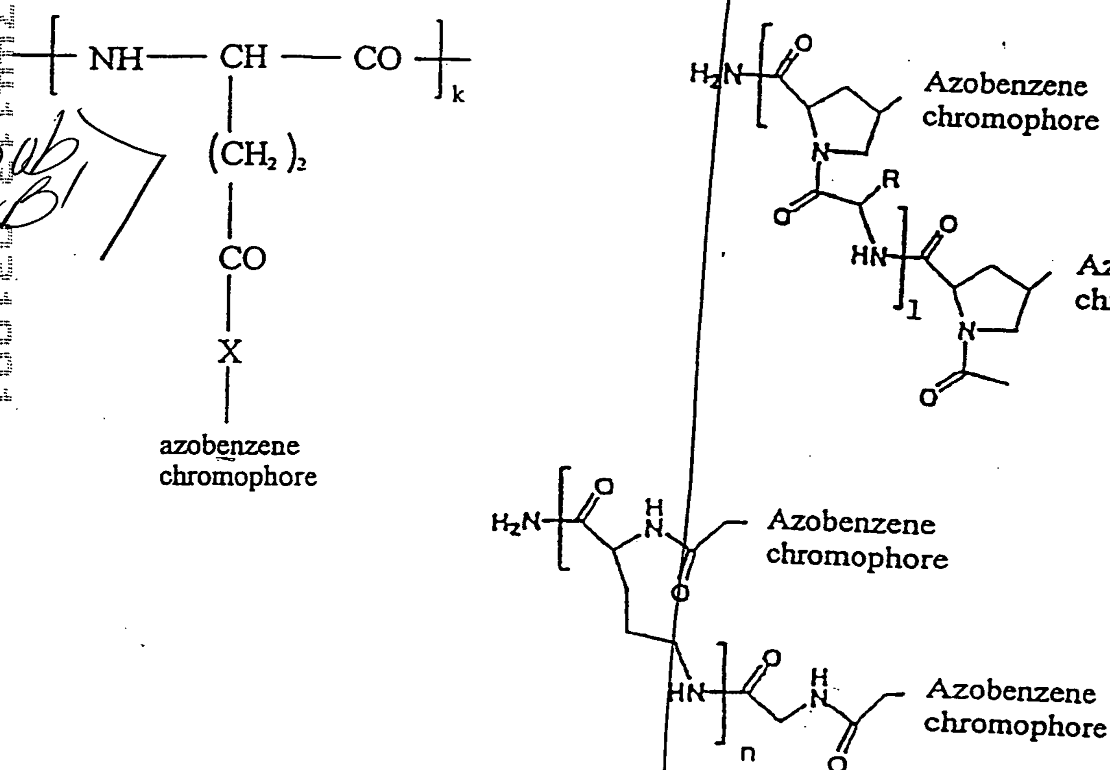
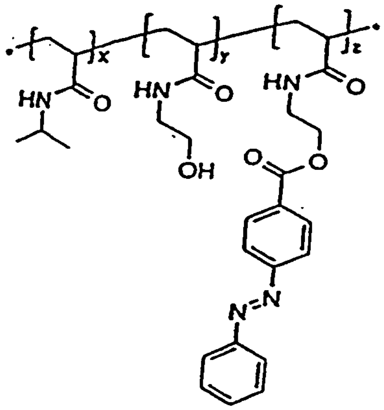
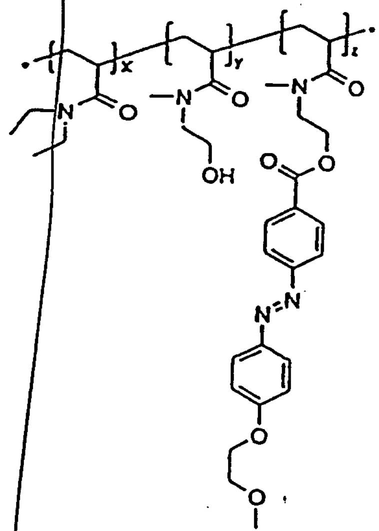
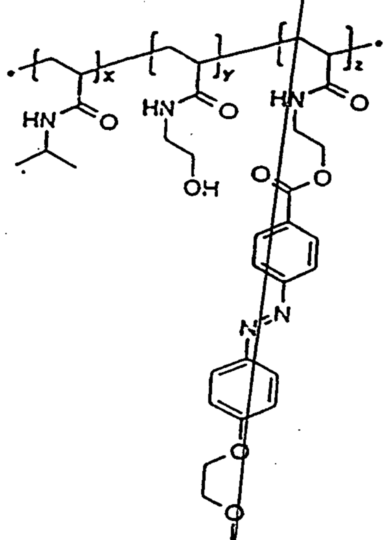


where X is selected from the group comprising NH and O,
where the azobenzene chromophore is defined as in claim 41, and
where k, n and l are selected from the range: $1 \leq (k \text{ or } l \text{ or } n) \leq 500$.

47. Substrate structure according to ~~one of the~~ claim~~s~~ 39 ~~- 41~~, characterized in that said poly-acrylamide is selected from the group comprising







where x is selected from the range: $0.2 \leq x \leq 1$,

y is selected from the range: $0.1 \leq y \leq 1$,

z is selected from the range: $0.005 \leq z \leq 0.025$, and

$x + y + z = 1$ for all combinations of x, y and z.

48. Substrate structure according to one of the claims 39-44, characterized in that said polyvinyl alcohol is selected from the group comprising

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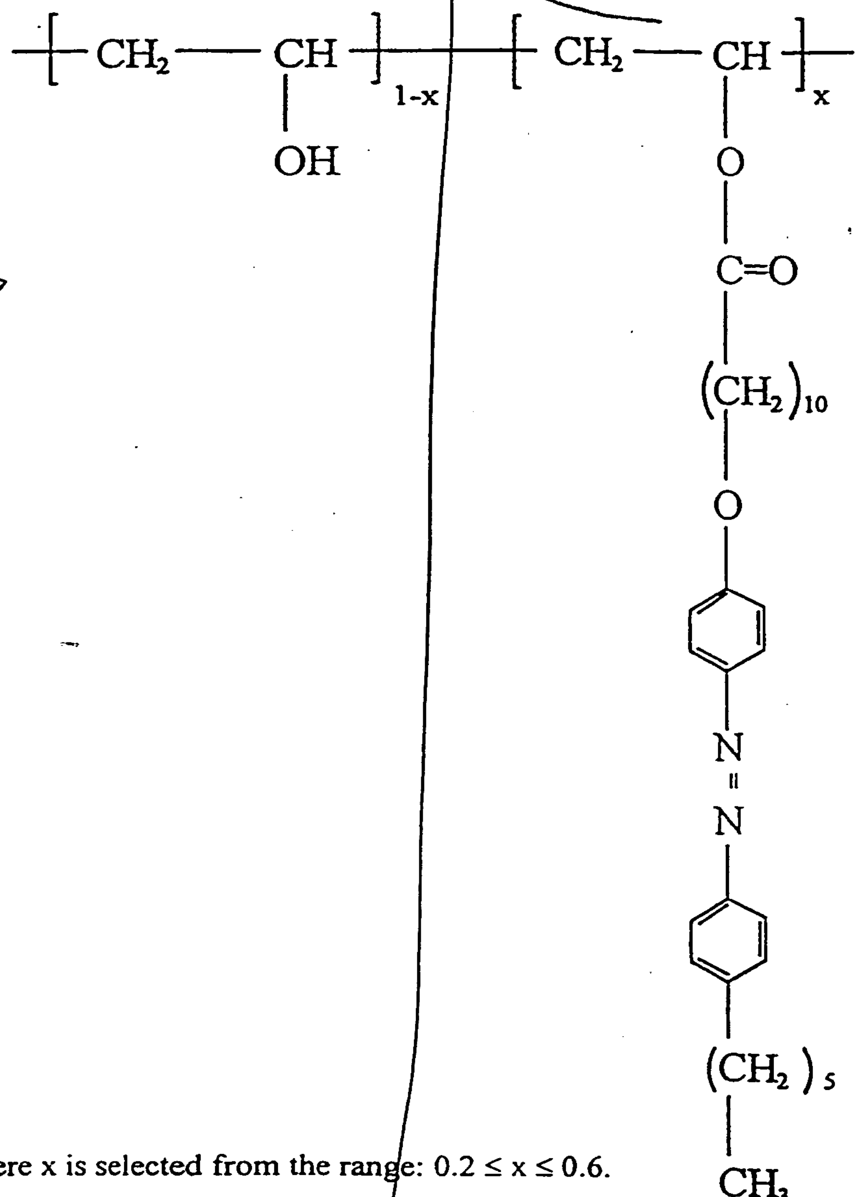

where x is selected from the range: $0.2 \leq x \leq 0.6$.

49. Substrate structure according to one of the claims 30 to 32, characterized in that said combined alignment layer comprises at least one type of azosilane.

50. Substrate structure according to claim 49, characterized in that said azosilane is selected from the group comprising

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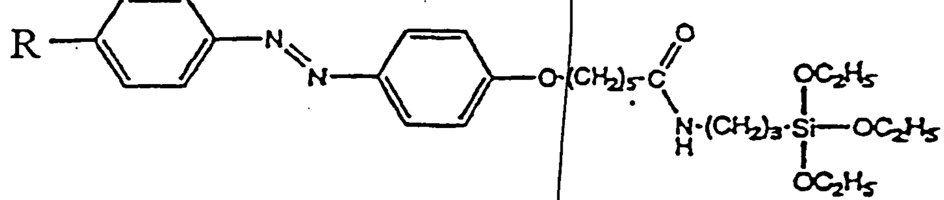


where R is selected from the group comprising CN, NO_2, OCH_3, H, CH_3, $(CH_2)_3CH_3$, F, Cl, Br, CF_3, C_6H_5, $O(CH_2)_2OCH_3$ and $(CH_2)_5CH_3$.

51. Substrate structure according to one of the claims 30 to 32 or 39 to 50, characterized in that said combined alignment layer has a thickness of 20 nm to 350 nm, preferably 200 nm.

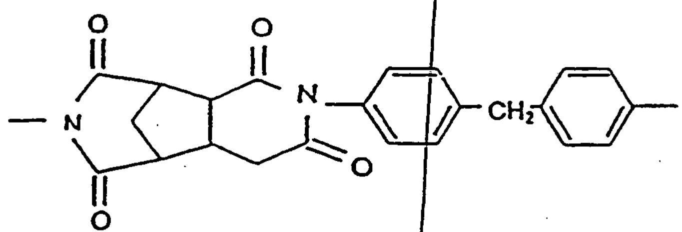
52. Device for monitoring cell or neuron activity, comprising:
- a basic substrate (1)
- at least one electronic device (20),
- at least one neuron or cell (10), being coupled to the respective electronic device (20) so that an activity of said at least one neuron or cell (20) influences the electronic device and produces measurable reaction and/or vice versa,

characterized in that it further comprises
- an alignment layer (2) on said substrate and/or at least partially on said electronic device, and
- a mono- or multi-layer of a liquid crystal material (3) on said alignment layer (2); or comprises
- a combined alignment layer.

53. Device according to claim 52, characterized in that said at least one alignment layer (2) is a polymeric alignment layer.

54. Device according to claim 52 ~~or 53~~, characterized in that said alignment layer (2) is a polyimide.

55. Device according to claim 54, characterized in that said polyimide is represented by the following structure:

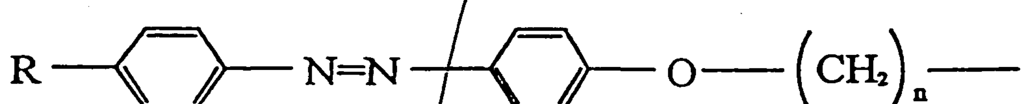


56. Device according to ~~one of the~~ claims 52 ~~to 55~~, characterized in that said liquid crystal material (3) is 4-Octyl-4-biphenyl carbonitrile (8CB) and/or 4-Pentyl-4-biphenyl carbonitrile (5CB).

57. Device according to claim 52, characterized in that said combined alignment layer comprises polymeric material selected from the group comprising polyester, polypeptide, polyacrylamide, polyvinyl alcohol, polyacrylate, polymethacrylate, polyurea and polyamide.

58. Device according to claim 57, characterized in that said polymeric material has at least one azobenzene chromophore covalently attached.

59. Device according to claim 58, characterized in that said azobenzene chromophore is represented by the formula:



where R is selected from the group comprising CN, NO_2, OCH_3, H, CH_3, $(CH_2)_3CH_3$, F, Cl, Br, CF_3, C_6H_5, $O(CH_2)_2OCH_3$ and $(CH_2)_5CH_3$,
and where n is selected from the range: $0 \leq n \leq 12$.

60. Device according to ~~one of the~~ claim~~s~~ 57 ~~- 59~~, characterized in that said polyester is a sidechain liquid-crystalline polyester.

61. Device according to claim 60, characterized in that said sidechain liquid-crystalline polyester is an azobenzene sidechain liquid-crystalline polyester.

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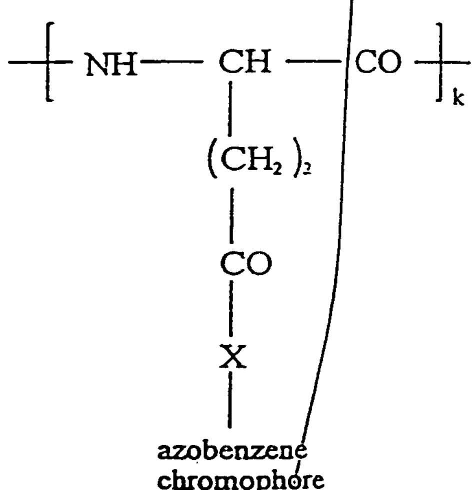
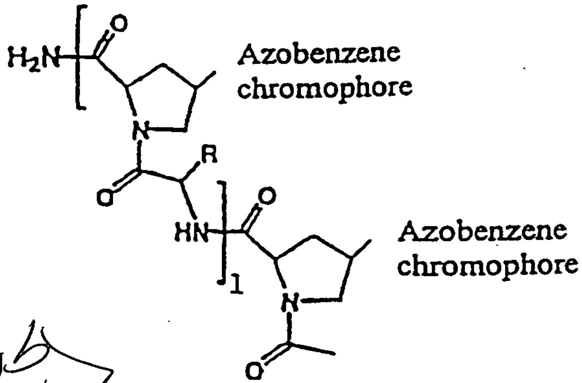
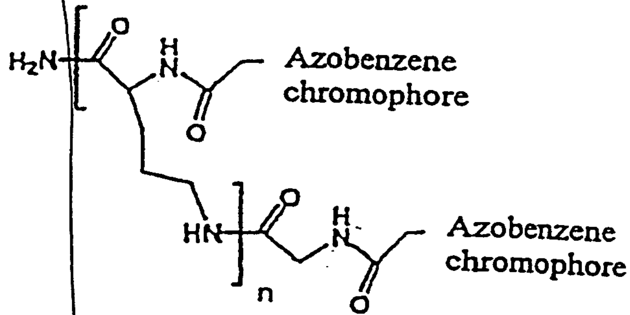
62. Device according to claim 61, characterized in that said azobenzene sidechain liquid-crystalline polyester is selected from the group comprising P6a12, P6a10, P8a10, P10a10, P8a12 and P10a12.

63. Device according to ~~one of the~~ claim~~s~~ 57 ~~- 59~~, characterized in that said polypeptide is selected from the group comprising polyglutamate, polyproline and polyornithine.

64. Device according to claim 63, characterized in that said polypeptide is selected from the group comprising







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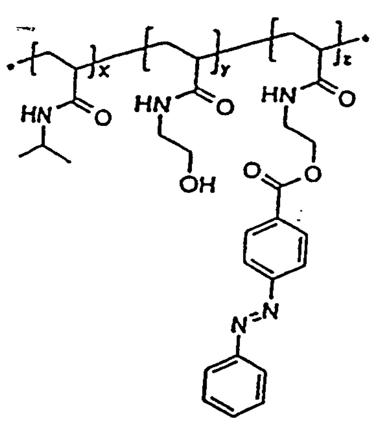
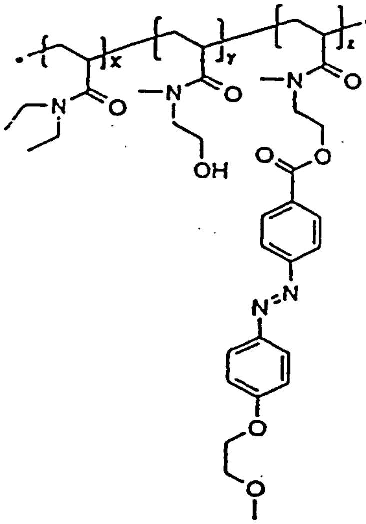
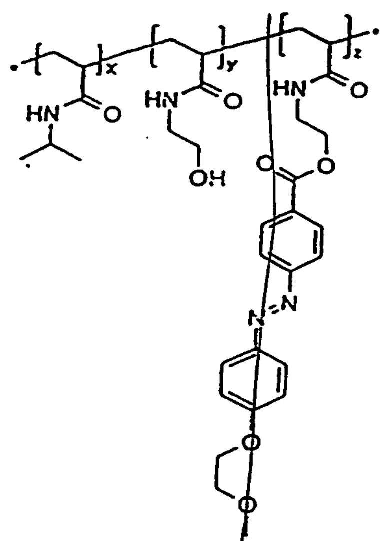
where X is selected from the group comprising NH and O,
where the azobenzene chromophore is defined as in claim 59, and
where k, n and l are selected from the range: $1 \leq (k \text{ or } l \text{ or } n) \leq 500$.

65. Device according to ~~one of the~~ claim~~s~~ 57 ~~, 59~~, characterized in that said polyacrylamide is selected from the group comprising







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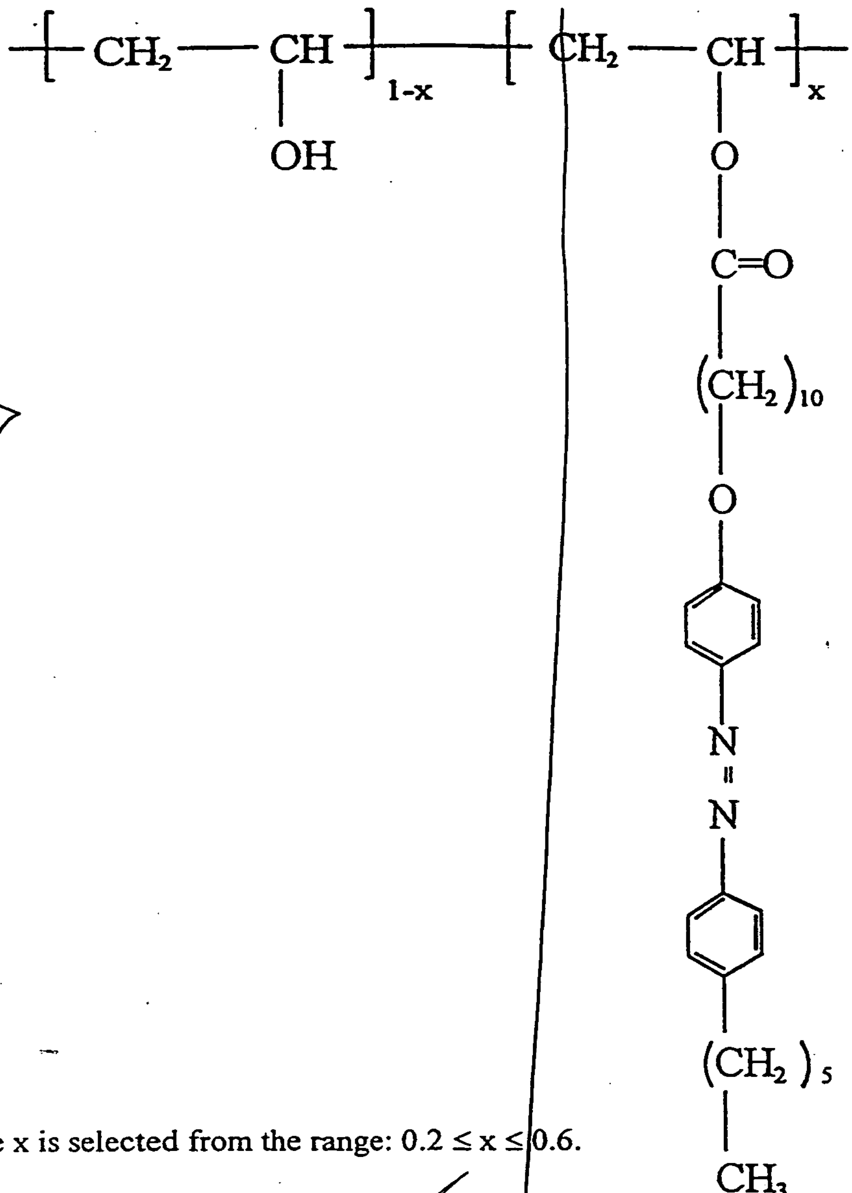
where x is selected from the range: $0.2 \leq x \leq 1$,

y is selected from the range: $0.1 \leq y \leq 1$,

z is selected from the range: $0.005 \leq z \leq 0.025$, and

$x + y + z = 1$ for all combinations of x, y and z.

66. Device according to ~~one of the~~ claims 57 ~~- 59~~, characterized in that said polyvinyl alcohol is selected from the group comprising



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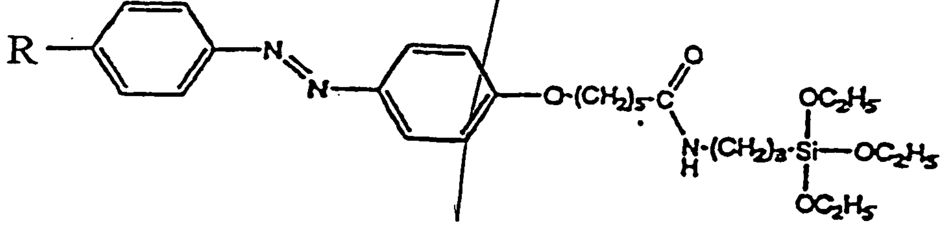
where x is selected from the range: $0.2 \leq x \leq 0.6$.

67. Device according to claim 52, characterized in that said combined alignment layer comprises at least one type of azosilane.

68. Device according to claim 67, characterized in that said azosilane is selected from the group comprising



where R is selected from the group comprising CN, NO_2, OCH_3, H, CH_3, $(CH_2)_3CH_3$, F, Cl, Br, CF_3, C_6H_5, $O(CH_2)_2OCH_3$ and $(CH_2)_5CH_3$.

69. Device according to ~~one of the~~ claim~~s~~ 52 ~~to 68~~, characterized in that said at least one electronic device (20) is a microelectrode.

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70. Device according to one of the claims 52 ~~to 68~~ characterized in that said at least one electronic device (20) is a field effect transistor (FET).

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71. Device according to claim 70, characterized in that said neuron or cell (10) is located on top of the non-metallized gate of said field effect transistor (20).

72. Use of a substrate structure comprising a basic substrate (1) and an alignment layer (2) and a layer of liquid crystal material (3), or a combined alignment layer, especially according to ~~one of the~~ claim~~s~~ 30 ~~to 51~~, for neurite outgrowth or cells and/or a neuronal network on it.

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73. Use of a device comprising a basic substrate (1), at least one electronic device (20), at least one neuron or cell (10), being coupled to the respective electronic device (20) so that an activity of said at least one neuron/cell (20) influences the electronic device and produces measurable reaction and vice versa, and an alignment layer (2) on said substrate and/or at least partially on said electronic device, a mono- or multi-layer of a liquid crystal material (3) on said alignment layer (2), or a combined alignment layer, especially according to ~~one of the~~ claim~~s~~ ~~52 to 71~~ 12, for monitoring cell or neuron activity, especially as a model system for investigating brain functions and as a development tool for designing software, working comparable to neuronal networks.

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